Thermal Stress

Heat & Cold Stress

Occupational Safety & Health Bureau

Montana Department of Labor & Industry

Prepared for Montana Employers
by the

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Thermal Stress

Introduction

Workers in Montana are exposed to temperature extremes in both hot and cold working environments. Outdoor temperatures in Montana can vary between -40 and 100 F, creating hazards of cold and heat stress.

Thermal stress also is a problem in many indoor operations including smelting, mining, laundries, kitchens, bakeries, electrical utilities (particularly boiler rooms), foundries, brick firing and ceramic operations, and work in refrigerator rooms or freezers.

The use of personal protective equipment (PPE) and clothing can also create a risk for heat stress which should be considered in the selection of the equipment and determining workers work rest cycle.

Thermal stress can also increase the risks of accidents in the workplace. Thermal stress can fatigue workers making them tired and careless. Workers may have a hard time concentrating on work and ignore safety. This booklet provides an overview of thermal (heat and cold) stress, guidelines for worker protection, examples of safety and health problems, and sources for additional information.

The Occupational Safety and Health Administration (OSHA) does not have a special standard for thermal stress. But because thermal stress is known as a serious hazard, workers are protected under the General Duty Clause of the Occupational Safety and Health Act. The clause says employers must provide A employment free from recognized hazards causing or likely to cause physical harm.≅

I. Heat Stress

Heat stress is caused by a combination of factors and tends to increase body temperature, heart rate, and sweating.

A. Sources of Heat Stress

Sources of heat to the body are **radiation**, which is actual infrared radiation, as from the sun or hot objects; **convection**, from hot air surrounding the worker and its movement; **conduction**, as with contact with hot objects; and **metabolic**, generated from within the body through work. Metabolic heat is the source that has the greatest potential to overheat the body; it can be 10 to 100 times the contribution of the other factors. Work involving muscle motion generates much more heat than isometric work. The core of the body is heated by metabolic heat, while other sources heat the peripheral members and skin.

B. The Body=s Reaction to Heat.

To keep internal body temperatures within safe limits, the body must get rid of its excess heat, primarily through varying the rate and amount of blood circulation through the skin and the release of sweat from glands. The heart begins to pump more blood, blood vessels expand to accommodate the increased flow, and the microscopic blood vessels (capillaries) which thread through the upper layer of the skin begin to fill with blood. The blood circulates closer to the surface of the skin, and excess heat is lost to the cooler environment. The cooled blood returns to the core of the body and picks up more heat and carries it to the

surface.

If heat loss from increased blood circulation through the skin is not adequate, the brain continues to sense overheating and signals the sweat glands in the skin to shed large amounts of sweat onto the surface of the skin. Evaporation of sweat cools the skin, eliminating heat from the body.

As environmental temperatures approach normal skin temperature, cooling of the body becomes more difficult. If air temperature is warm as or warmer than the skin, blood brought to the body surface cannot lose its heat. The heart continues to pump blood to the surface, the sweat glands poor liquids containing electrolytes onto the surface of the skin and the evaporation of the sweat becomes the principal effective means cooling.

If the sweat in not removed from the skin by evaporation it will not cool the body. Under conditions of high humidity, the evaporation of sweat from skin is decreased and the body=s efforts to maintain an acceptable body temperature may be significantly impaired. With so much blood going to the external surface of the body, less is going to the active muscles, the brain, and other organs; strength declines; and fatigue occurs sooner than normal. Alertness and mental capacity also may be affected. Workers who must perform delicate or detailed work may find their accuracy decrease, and others may find their comprehension and retention of information lowered.

C. Safety Problems.

Heat tends to promote accidents due to the slipperiness of sweaty palms, dizziness, fatigue, decreased alertness, and/or the fogging of eyeglasses. Increased body temperature and physical discomfort promote irritability, anger, and other emotional states which sometimes cause workers to overlook safety procedures or to divert attention from hazardous tasks. When heat stress and working long shifts (10-16 hour days) are combined there is a greatly increased risk for accidents or health problems.

Workers operating or working around heavy equipment need to be alert at all times. If workers are not aware of dangerous situations around heavy machinery they could be crushed or ran over. Equipment operators must be aware of all personal and equipment around them. Workers need to be given rest periods to maintain alertness and help the body recover from heat stress. The work rest cycles will be discussed later in this booklet.

D. Health Problems (HIGH TEMP + HIGH HUMIDITY + PHYSICAL WORK = HEAT ILLNESS)

Excessive exposure to a hot work environment can bring about a variety of heat-induced disorders. It is important that workers and supervisors know what the signs and symptoms of these disorders are, and how to prevent and treat them.

1. Heat Stroke. Heat stroke is the most serious health problem associated with working in hot temperatures. It occurs when the body=s temperature regulatory system fails and sweating becomes inadequate or stops entirely. Unless the victim receives quick and appropriate treatment, **death** may occur.
Symptoms - Chills, restlessness, irritability, and mental confusion.
Signs - Euphoria, red face, disorientation, hot, dry skin (usually), sweating stops, erratic behavior, collapse, shivering, unconsciousness, convulsions, and body temperature $\geq$ 104 F.
Cause - Excessive heat exposure combined with high workload.

First Aid - Immediate professional medical treatment, replace fluids, and aggressive cooling (ice packs).
Prevention - Acclimation, healthy life style, appropriate work-rest cycle, fluid intake, proper diet, and self-determination of heat stress exposure.

2. Heat Exhaustion. Heat exhaustion is caused by the loss of large amounts of fluid from sweating, sometimes with excessive loss of salt. A worker suffering from heat exhaustion still sweats but experiences extreme fatigue or loses consciousness. If heat exhaustion is not treated, the illness may advance to heat stroke.

Symptoms - Fatigue, weakness, blurred vision, dizziness, and headaches.
Signs - High pulse rate, profuse sweating, low blood pressure, pale face, clammy skin, collapse, vomiting, and slightly increased body temperature.
Cause - Dehydration, low level of acclimation, and low level of physical fitness.
First Aid - Lie down flat on back in cool environment, drink water, cool skin with cool spray mist or wet cloth, and loosen clothing.
Prevention - Drink water or other fluids frequently, add salt to food, take rest breaks in cool area, and acclimation.

3. Dehydration.

Symptoms - No early symptoms, fatigue, weakness, and dry mouth.
Signs - Loss of work capacity and increased response time.
Cause - Excess fluid loss and alcohol consumption.
First Aid - Fluid and salt replacement.
Prevention - Drink water frequently and add salt to food.

4. Heat Syncope.

Symptoms - Blurred vision, fainting, and normal body temperature.
Signs - Brief fainting.
Cause - Pooling of blood in the legs and skin from prolonged static posture and heat exposure.
First Aid - Lie on back in cool environment and drink water.
Prevention - Flex leg muscles several times before moving and stand or sit up slowly.

5. Heat Cramps. Heat cramps are painful spasms of the muscles that occur among those who sweat profusely in heat, drink large quantities of water, but do not adequately replace the body=s salt loss.

Symptoms - Painful muscle cramps.
Signs - Incapacitating pain in muscle
Cause - Electrolyte imbalance caused by prolonged sweating without fluid and salt replacement, can be caused by too little or too much salt.
First Aid - Rest in cool environment, Massage muscles, and drink carbohydrate-electrolyte replacement liquids.
Prevention - If workers expect to be doing heavy work in hot environment add salt to diet.

6. Heat Rash. Heat rash is likely to occur in hot, humid environments where sweat is not easily removed from the surface of the skin by evaporation and skin remains wet most of the time.

Symptoms - Itching red skin, and reduced sweating.
Signs - Skin eruptions.
Causes - Prolonged, uninterrupted sweating, and poor hygiene.
First Aid - Keep skin clean and dry, change from wet cloths to dry cloths, and reduce heat exposure.
Prevention- Keep skin clean and periodically allow skin to dry.

E. Control Methods

1. Engineering Controls.

General ventilation is used to dilute hot air with cooler air. This technique works better in cooler climates than in hot ones. A permanently installed ventilation system usually handles larger areas or entire buildings. Portable or local exhaust systems may be more effective or practical in smaller areas.

Air treatment / air cooling differs from ventilation because it reduces the temperature of the air by removing the heat and sometimes the humidity from the air.

Air conditioning is an effective method for cooling, but it is expensive to install and operate. An alternative to air conditioning is the use of chillers to circulate cool water through heat exchangers over which air from the ventilation system is then passed.

Local air cooling is used to cool air in a specific location, usually set up near a hot area or in a break area. Cool rooms can be used to enclose a specific workplace or to offer a recovery area near hot jobs. A portable blower with a built-in air chiller can also be used.

Convection, fans can be set up in hot areas and can increase heat exchange and the rate of evaporation, provided that the air temperature is less than body temperature.

Insulating hot surfaces or tools that generate or conduct heat can also reduce heat conduction to workers.

Heat shields can be used to reduce radiant heat when placed between heat source and workers. Polished surfaces make the best barriers, although special glass or metal mesh surfaces can be used if visibility is a concern. Shields should be located so that they do not interfere with air flow, unless they are being used to reduce convective heating.

Mechanization of work procedures can often make it possible to isolate workers from the heat source (air-conditioned booth) and increase productivity by decreasing the rest time needed and metabolic heat produced.

Reduce air humidity by removing the water from the air with water chillers or mechanical refrigeration. The lower the humidity in the air the greater the rate of evaporation of sweat.

2. Administrative and Work Practice Controls

Acclimation

The human body can adapt to heat exposure to some extent. This physiological adaptation is called acclimation. After a period of acclimation, the same activity will produce fewer cardiovascular demands. The worker will sweat more efficiently and thus will more easily be able to maintain normal body temperatures. A worker can be acclimatized by being introduced into the hot environment gradually, for example for a worker with experience in high heat levels - 50% exposure on day one, 60% on day two, 80% on day three, and 100% on day four. For new worker who will be similarly exposed, the regimen should be 20% on day one, with a 20 % increase in exposure each additional day. A worker may lose acclimation after a week or so of non-exposure and has to be reacclimated. Heat has less of an effect on workers in good physical condition and good health, if unhealthy or unfit workers are working in a hot environment they must be closely monitored for signs of heat stress and strain.

Fluid Replacement.

In the course of a day=s work in the heat, a worker may produce as much as 2 to 3 gallons of sweat, water intake should be about equal to the amount of sweat produced. Most workers exposed to hot conditions drink less fluids than needed because of an insufficient thirst drive. A worker should not depend on thirst to signal when and how much to drink. Instead, the worker should drink one cup of fluid every 15-20 minutes to replenish the necessary fluids in the body.

There is no optimum temperature of drinking water, but most people tend not to drink warm water as readily as cool (50 - 60 F) water. Other liquids can be used as well such as dilute iced tea, fruit juices, and cool aid, but water is the best replacement. Workers should be encouraged or required by company policy to drink water frequently in hot conditions. Ample supplies of liquids should be placed close to the work area. Individual water canteens could be used for workers that work in a large area. Individual drinking cups should be provided, never use a common drinking cup. Workers should be encouraged to salt their foods well during the hot season, salt tablets should not be used as a salt replacement.

If possible, for workers working for extended periods of time in hot environments, check body weight just before drinking. Workers should not be allowed to lose more than 1.5% of body weight in a day.

Work-Rest Cycles

Workers exposed to heat stress need more break periods than unexposed workers do. Rest breaks are used to reduce the metabolic heat produced by the body during work and to aid in cooling. When determining work-rest cycles the Wet Bulb Globe Temperature (WBGT) and the workload must be evaluated. Guidelines for evaluating employee heat stress are found in the 1999 ACGIH publication, *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices.(ACGIH TLV Book)* pages 169-180.

Supervisors should take the responsibility of protecting their workers, in hot conditions workers should be allowed to take rest breaks when they feel fatigued. Rest areas should be set up in cool rooms or in the shade, workers should be required to drink water or other liquids during breaks. Shorter but frequent work-rest cycles are the greatest benefit to the workers. Individual work periods should not be lengthened in favor of prolonged rest periods. Please see ACGIH TLVs book for recommended work-rest cycles.

Hot jobs should be scheduled for the cooler parts of the day, and routine maintenance and repair work in hot areas should be scheduled for cooler seasons of the year if feasible.

Training

Training is the key to good work practices. Unless all employees understand the reasons for using new, or changing old, work practices, the program will not fully succeed. An effective heat stress training program should include at least the following elements:

- Knowledge of the hazards of heat stress;
- Recognition of predisposing factors, danger signs, and symptoms;
- Awareness of first-aid procedures for, and the potential effects of heat-related disorders;
- Employee responsibilities in avoiding heat stress;
- Use of protective clothing and equipment;
- Physical fitness to prevent heat-related disorders;
- Fluid replacement;
- Dangers of drugs and alcohol in hot work environments; and
- Purpose and coverage of environmental and medical surveillance programs.

Monitoring Heat Strain on the Body

There are several easy ways to monitor heat strain: core temperature, recovery heart rate, and dehydration rate. The following guidelines are established to indicate when further evaluation of the work environment is needed.

Core temperature is most accurately measured as rectal temperature, but oral temperature plus one degree F. is a reasonably good estimator. The criterion level is a core temperature over 100.4 deg. F. (99.4 deg. F oral temperature). If the worker has an elevated core temperature over 100.4 F the worker should be cooled and their work load and work time should be decreased. More extensive monitoring should be done if this condition exists.

Recovery heart rate, measured during the last 30 seconds of the first minute after stopping work and sitting down (called P1), should be less than 110 beats per minute (bpm), or, in the last 30 seconds of the first three minutes (called P3), the rate should be less than 90 bpm. For acceptable recovery, P1 - P3 should be greater than 10 bpm.

The third measure is body weight, measured just before a water break or water intake after a shift. Criterion level is body weight loss is 1.5% or more. When using the weight method, take care not to weigh tools in the pocket, wet clothing, etc. It is best to weigh the workers in underwear before water consumption at end of shift.

3. Personal Protective Equipment

Reflective Clothing, which can vary from aprons and jackets to suits that completely enclose the worker from neck to feet, can stop the skin from absorbing radiant heat. However, since most reflective clothing does not allow air exchange through the garment, the reduction of radiant heat must more than offset the corresponding loss in evaporative cooling. Reflective clothing should be worn as loosely as possible. In

situations where radiant heat is high, auxiliary cooling systems can be used under the reflective clothing.

Auxiliary Body Cooling can also be used to reduce some of the heat stress. Auxiliary cooling options include: ice vests, water-cooled garments, circulating air, and wetted terry cloth coveralls or cotton suits (effective under low humidity).

Respirator and Personal Protective Equipment Usage increases the stress on a worker, and this stress contributes to overall heat stress. Chemical protection suits will also add to the heat stress problem. The effects of this protective equipment must be considered when determining workloads and work-rest cycles.

Workers should wear hats that protect their head, face, and neck from sunburn. A broad spectrum sunburn cream with a SPF of 15 + should be applied to skin that is exposed on sunny days. A wetted scarf can also be worn around the neck to aid in cooling.

How to Protect Workers from Heat Stress

- Learn the signs and symptoms of heat-related disorders and what to do to help the worker.
- Train workers about heat-related illnesses.
- Perform the heaviest work in the coolest part of the day.
- Slowly build up tolerance to the heat and work activity, acclimation (usually takes up to 2 weeks).
- Use the buddy system (work in pairs).
- Drink plenty of water (one cup every 15-20 minutes).
- Wear light, loose-fitting, breathable clothing.
- Take frequent short breaks in cool areas (allow body to cool down).
- Avoid eating large meals before working in hot environments.
- Avoid caffeine and alcoholic beverages.
- Use hats and sunscreen to prevent sunburns.

Workers Are at Increased Risk When

- They wear personal protective equipment (respirators or suits).
- They have had a previous heat-related illness.
- They take certain medications or drink alcohol.

II. Cold Stress

Montana employers must also consider cold stress as a workplace hazard. Workers that work outside in the winter, fall, and spring months can be exposed to low temperatures and windchill. Indoor operations that involve refrigeration also create cold stress hazards. Under the OSHA General Duty Clause employers are responsible for the safety and health of their employees, cold stress is covered under this statute.

Cold stress is the loss of body heat to the environment. Low temperature, wind, and wetness have a combined effect on the body to create cold stress, injuries, and illness. Cold-related disorders such as hypothermia and frostbite can kill or injury workers. Employers and employees should be aware of cold stress hazards, cold-related disorders and how to treat and prevent them.

A. Sources of Heat Loss

Body heat is lost to the environment by four different routes: radiation, conduction, convection, and evaporation. **Radiation** is the loss of body heat to the colder air in the environment due to the temperature difference. **Conduction** is loss of heat through direct contact between objects, heat transfer. Water conducts heat away from the body 25 times faster than air. Usually conductive heat loss accounts for about 2% of the overall loss, but with wet cloths the loss increases to around 5 times. In **convection**, warm molecules against the surface of the body are moved away and replaced with cold molecules. Wind chill is an example of the effects of air convection, the wind chill table gives a reading of the amount of heat lost to the environment relative to still air temperature. In **evaporation**, heat and fluid is lost to the environment from sweating and respiration, a decreased fluid level makes the body more susceptible to hypothermia and other cold injuries.

B. The Body=s Reaction to Cold

The body=s first response to cold stress is to conserve body heat by reducing blood circulation through the skin. This makes the skin an insulating layer. Next, the muscles in the body begin to shiver, which increases the rate of metabolism. Shivering is a good sign that cold stress is significant and that hypothermia may be present. The primary response to cold stress is behavioral. Behaviors include increasing clothing insulation, increasing activity, and seeking warmth.

C. Safety Problems

Many of the safety problems created by the cold are similar to the problems from heat stress. Cold stress can make workers fatigued or drowsy which can lead to accidents. Eyeglasses can become fogged and walking surfaces slippery increasing the risk for slips and falls. Decreased body temperature and physical discomfort promote irritability, anger, and other emotional states which can effect workers alertness and attitudes towards safe working procedures. Useful physical and mental work is limited when severe shivering occurs.

D. Health Problems (LOW TEMP + WIND + WETNESS = COLD INJURIES & ILLNESS)

Excessive exposure to cold stress can bring about a variety of cold-induced disorders. It is important that workers and supervisors know what the signs and symptoms of these disorders are, and how to prevent and treat them.

1. Hypothermia. Normal body temperature (98.6 F / 37 C) drops to or below 95 F (35 C). The core body temperature decreases to a level at which normal muscular and brain functions are impaired. Wet clothes dramatically increase the risk of developing hypothermia. Hypothermia can lead to death if the body is not treated.

Symptoms - Chills, pain in extremities, fatigue, and drowsiness.
Signs - Euphoria, loss of coordination, violent shivering, slurred speech, slow and weak pulse, irrational behavior, collapse, unconsciousness, body temperature < 95 F, pupils dilate, and pale skin.
Causes - Cold temperatures, wetness, improper clothing, exhaustion, dehydration, poor food intake, no knowledge of hypothermia.
First Aid - Move to warm dry area, remove wet clothing, wrap in dry blankets, modest external warming (external heat packs), drink warm sweet fluids, and take to the hospital.

2. Frostbite. Freezing in deep layers of skin and tissue, usually affects the finger, hands, toes, feet, ears, and nose.

Symptoms - Burning sensation at first, coldness, numbness, and tingling.
Signs - Skin color white or grayish yellow to reddish violet to black, blisters, and skin feels Awooden≅.
Causes - Exposure to cold, and poor circulation.
First Aid - Move to warm area and remove wet clothing, external warming (warm water), drink warm sweet fluids, do not rub affected area, and take to the hospital.

3. Trench Foot is caused from wet feet and exposure to cold temperatures above freezing.

Symptoms - Severe pain, tingling, and itching in feet and legs.
Signs - Edema, blisters, reduced touch sensation.
Causes - Exposure to cold (above freezing) and dampness.
First Aid - Similar to frostbite.

E. Control Methods

The most effective controls for cold stress is training and work practices, workers must know how to protect themselves from the cold. Workers should replace wet clothing as soon as possible in temperatures less than 36 F and continuously be replacing fluid with warm, sweet, non-caffeine containing drinks. Clothing should be layered and gloves or mittens should be worn in cold weather.

1. Engineering Controls.

! Provide warming shelters if exposures occur below 19 F.
! Provide for general or spot heating, including hand warming.
! Reduce conductive heat transfer, do not use metal chairs to uninsulated tools.
! Provide wind barriers

2. Administrative and Work Practice Controls.

! Train workers about cold stress, cold-related disorders, and first aid.
! Set up work -rest cycles according to *ACGIH TLVs Book.*
! Schedule work at warm times.
! Move work to warm areas.
! Encourage self-pacing and extra breaks if required.
! Use the buddy system (work in pairs).
! Select proper clothing for cold, wet, and windy conditions.
! Drink warm, sweet fluids, avoid caffeine and alcohol.
! Recognize the environmental conditions that lead to cold stress.

3. Personal Protection.

! Properly selected, insulated, and layered clothing.
! Waterproof boots and gloves.
! Eye protection for snow or ice-covered terrain.
! Personal heaters.

Resources

Information about thermal stress can be obtained from the sources listed bellow:

1. U.S. Department of Labor, **Occupational Safety & Health Administration**, Public Affairs Office-Room 3647, 200 Constitution Ave., Ashington, D.C. 20210.
Phone: 1-202-693-1999.
www.osha.gov

2. **National Institute for Occupational Safety and Health**. Department of Health and Human Services, 200 Independence Ave. SW 317B, Washington, DC 20201.
Phone: 1-800-356-4674, 1-800-35-NIOSH
www.niosh.gov

3. **American Conference of Governmental Industrial Hygienists (ACGIH)**. 1330 Kemper Meadow Drive, Cincinnati, OH 45240-1634.
Phone: 1-513-742-2020, Fax: 1-513-742-3355
www.acgih.org

Regulatory references are also available in some commercial safety catalogs.

4. Lab Safety Supply Inc., P.O. Box 1368, Janesville, WI 53547-1368.
Phone: 1-800-356-2501, Fax: 1-800-393-2287
www.labsafety.com

5. J.J. Keller & Associates, Inc., 3003 W. Breezewood Lane, P.O. Box 368, Neenah, WI 54957-0368
Free safety catalog available.
Phone: 1-800-531-8899, Fax: 1-800-727-7547
www.jjkeller.com

6. Conney Safety Products, 3202 Latham Drive, P. O. Box 44190, Madison, WI 53744-4190
Free safety catalog available
Phone: 1-800-356-9100 Fax: 1-800-845-9095
www.conney.com

Suggested reading:

Working in Hot Environments, is available free from National Institute for Occupational Safety and Health Publications, 4676 Columbia Parkway, Cincinnati, OH 45226; telephone (513) 533-8287

1999 ACGIH publication, ***Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices****.(ACGIH TLV Book)* pages 159-180. To order contact ACGIH, 1330 Kemper Meadow Drive, Cincinnati, OH 45240-1634. telephone (513) 742-2020, E-mail: pubs@acgih.org

For any safety and health questions please call the Safety Bureau at (406) 444-6401.